# FIRE INJURY IN ITS RELATION TO BARKBEETLE ATTACK:

by

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## INTRODUCTION:

That the effect of fire in pine forests of the Pacific Slope region has been studied in many of its aspects is indicated by the published information on this problem. One phase, which has been only briefly discussed in the literature now available, is that of barkbeetle infestations which follow in the wake of fires.*

It has been generally recognized that there is a direct relation between fire injury and subsequent insect damage on burned over areas. Two types of loss are involved--destruction of the merchantable value of fire-killed trees by wood boring insects, and the actual killing by barkbeetles of trees which would have otherwise survived the fire.

An increase in the numbers of barkbeetle infested trees is a frequent aftermath of the so called light fires which do but little apparent damage to mature timber. A very perceptible flare up of infestation in a burn will occur for one or two years following the fire. Many trees only moderately fire injured and apparently due to recover will succumb to the attacks of these beetles.

Such damage follows as a result of a sporadic local increase of barkbeetle population within the fire area which can only be explained by the assumption that numbers of beetles fly into the burned area from the surrounding forest. Because of fire injury certain trees become especially attractive to the beetles. The physiological basis for this attraction is but vaguely understood. The odor of fire scorched foliage and cambium may be an attractive influence, or the insects themselves may possess an instinctive ability to select those trees in which sap resistance has been weakened by fire injury, but it is evident that the influence is a very strong one in determining the behaviour of Dendroctonus beetles.

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* The Role of Fire in the California Pine Forests, S.B. Shaw and E.I. Kotok, U.S.D.A. Dept. Bull. No. 1294.

The multifold aspects of the interrelation of fire and insects damage raises many questions that are pertinent to the protection of pine forests. What type and what degree of fire injury makes trees attractive to barkbeetles? Are such trees capable of recovery if not attacked by ~~n~~ insects? Do barkbeetles "breed up" in fire areas, increasing their numbers to an epidemic status and then become agressive in uninjured trees in and around burned areas?

The answer can only be found by a careful study and analysis of the infestations which develop in and around burned over areas. Since 1917 the Bureau of Entomology has had underway studies of areas in the yellow pine districts of California and Oregon. The results now available indicate the tendencies to be expected under the conditions where these fires occurred. Seldom do any two fires occur under identical conditions and each presents its own individual complex of factors which may modify results. It cannot be claimed therefore that the results which are given in this paper will be found applicable to all fires under any conditions, but they are intended only to serve as a contribution toward the information which is being accumulated on this problem.

## THE MISTLETOE BURN .

### General Conditions of the Area:

One area where the more intensive studies have been carried on is known as the Mistletoe Burn in Southern Oregon. This fire, which occured October 31, 1917, burned over 800 acres on the slopes of the Siskiyou mountains 7 miles southeast of the town of Ashland. The elevations within the burn range from 3,000 to 4,000 feet, with exposures of the slopes mainly to the south and east. The timber type consists of a mixed stand of yellow pine and Douglas fir with a small amount of sugar pine intermixed. At the lower elevations and on the poorer sites brush cover predominated which graded into fairly well stocked mature stands of conifers on the more favorable slopes. There was abundant reproduction and new growth of conifers on the better sites. From a 100 percent cruise of the burned over area the ratio of merchantable timber of the more important species compared as follows:

| | |
|---|---|
| Yellow pine | 44.5% |
| Douglas fir | 52.5% |
| Sugar pine | 3 % |

### Studies of Area Preceding Fire:

Both the area that was burned and the surrounding forest had been under study since 1914. Annual cruises had been made in which all insect killed yellow pine and sugar pine had been marked and records filed in a study carried on to determine the progress of the barkbeetle infestation in the general region. Although the fire occurred accidentally from unknown origin, the status of the barkbeetle infestation at the time was definitely known.

## Character of the Fire:

In the open and mature stands the damage was typical of a ground fire of moderate severity. Seedlings and small reproduction were killed, a few butt scars were newly formed and old scars enlarged on the larger trees, but no merchantable trees were killed.

In the thickets of new growth and in brush cover on the steeper slopes the fire developed considerable intensity and either killed or consumed all forest cover. In sections of the area, where brush and trees of pole sizes were intermixed, the fire reached the crowns, burned away the foliage, and killed outright a considerable percent of the stand.

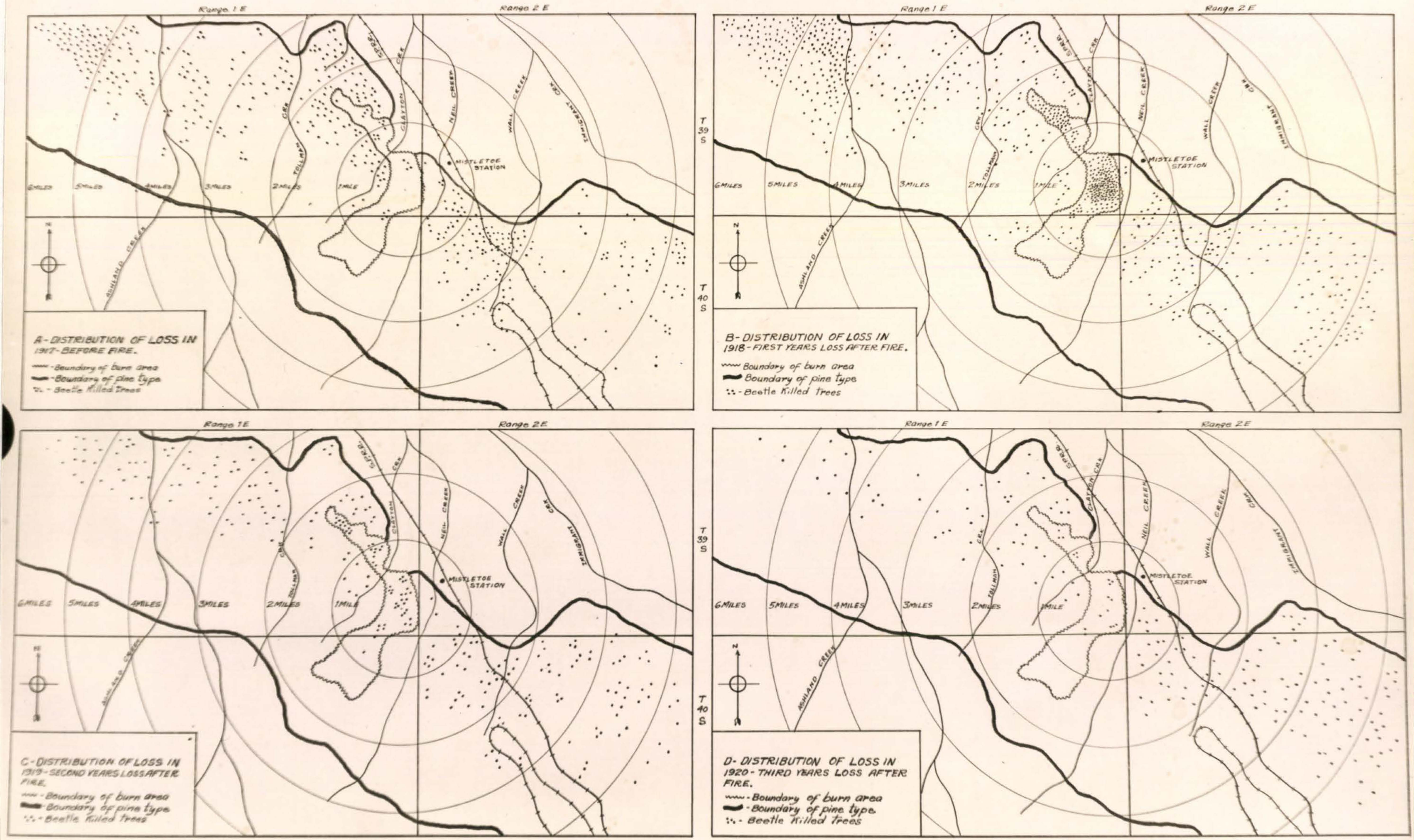
## Cruise of Fire Damage:

The following year in 1918 a cruise was made of the entire burn to determine the amount of damage to merchantable trees. As a basis for a study of subsequent insect attacks, all trees on the area were marked according to the nature of fire injury. A base line was run across the burn and the entire area was covered by strips, one tally wide run at right angles to this base line. All trees over 10 inches D. B. H. were examined and classified according to the degree of fire injury and marked according to class of injury for future reference. At the same time cruises were made in the surrounding areas and the loss analyzed by zones from one to six miles distant from the center of the

the burn. A similar cruise was made in November 1919 and final examination of the area in 1920. Fig. 1.

Limitations of Data:

This study was planned to determine the relation of the fire injured trees to subsequent barkbeetle attack and it was found unnecessary to consider trees under 10 inches D.B.H. in this respect. No quantitative date was taken on the destruction of seedlings, reproduction, brush, and other forest cover which was not of a merchantable character, although this was something of a factor in the amount of damage. Douglas fir also was thrown out of consideration as it was found that the only insects attacking this host in the burn were secondary borers and that such attacks were confined largely to fire killed trees. The percent of sugar pine was so small that it cut practically no figure. The study therefore is confined entirely to the western pine beetle infestation developing in the fire injured yellow pine.



A - DISTRIBUTION OF LOSS IN 1917 - BEFORE FIRE.

B - DISTRIBUTION OF LOSS IN 1918 - FIRST YEARS LOSS AFTER FIRE.

C - DISTRIBUTION OF LOSS IN 1919 - SECOND YEARS LOSS AFTER FIRE.

D - DISTRIBUTION OF LOSS IN 1920 - THIRD YEARS LOSS AFTER FIRE.

Range 1 E
Range 2 E
T 39 S
T 40 S
MISTLETOE STATION
6 MILES
5 MILES
4 MILES
3 MILES
2 MILES
1 MILE
TOLMAN CRK
CLAYTON CRK
S.P.R.R.
NEIL CREEK
WALL CREEK
EMIGRANT CRK
ASHLAND CREEK
N
Boundary of burn area
Boundary of pine type
Beetle Killed Trees

Fig 1 - Distribution of Dendroctonus brevicomis killed trees on the burn area and in the surrounding zones for one year before fire and for three years after - MISTLETOE BURN -

## Classification of Yellow Pine According to Fire Injury:

| Degree of fire injury: | No. trees: | Percent: | Volume: | Percent: |
|---|---|---|---|---|
| Class I - Uninjured by fire | 1,577 | 65.5% | 1,385,430 | 65. % |
| ClassII - Light fire injury | 573 | 24. % | 539,370 | 25. % |
| Class III - Medium fire injury | 113 | 4.8% | 120,360 | 5.6 % |
| Class IV - Heavy fire injury | 57 | 2.4% | 80,450 | 3.7% |
| Class V - Killed by fire | 80 | 3.3% | 16,720 | .7 % |
| Total | 2,400 | 100. % | 2,142,330 | 100. % |

Trees in classes II,III and IV are those which survived the fire but with varying degrees of injury. In all three classes the bole of the tree had been more or less blackened but without apparent injury to the cambium, except in classes III and IV. In Class II the foliage was partially scorched causing the needles to discolor. In Class III the foliage was scorched practically to the crown but not sufficiently to kill the terminal buds on lateral limbs and top. In Class IV the entire foliage was burned away and the terminal buds killed but the cambium still remained green at the time of the examination six months after the fire. The chart in Fig. 2 illustrates the comparative fire injury used in this classification.

Butt scars were considered but as few of these were formed by this fire and none were attacked by barkbeetles, this class of damage was eliminated in order to simplify the analysis of factors.

The amount of fire killed trees is relatively small and was confined to the smaller trees as shown by the fact that while 3.3% of the number of trees were killed by the fire these amounted to only .7% of the volume.

## Volume of Timber Killed by Barkbeetles within the Burn:

From May 1 to October 31, 1917, the season preceding the fire,

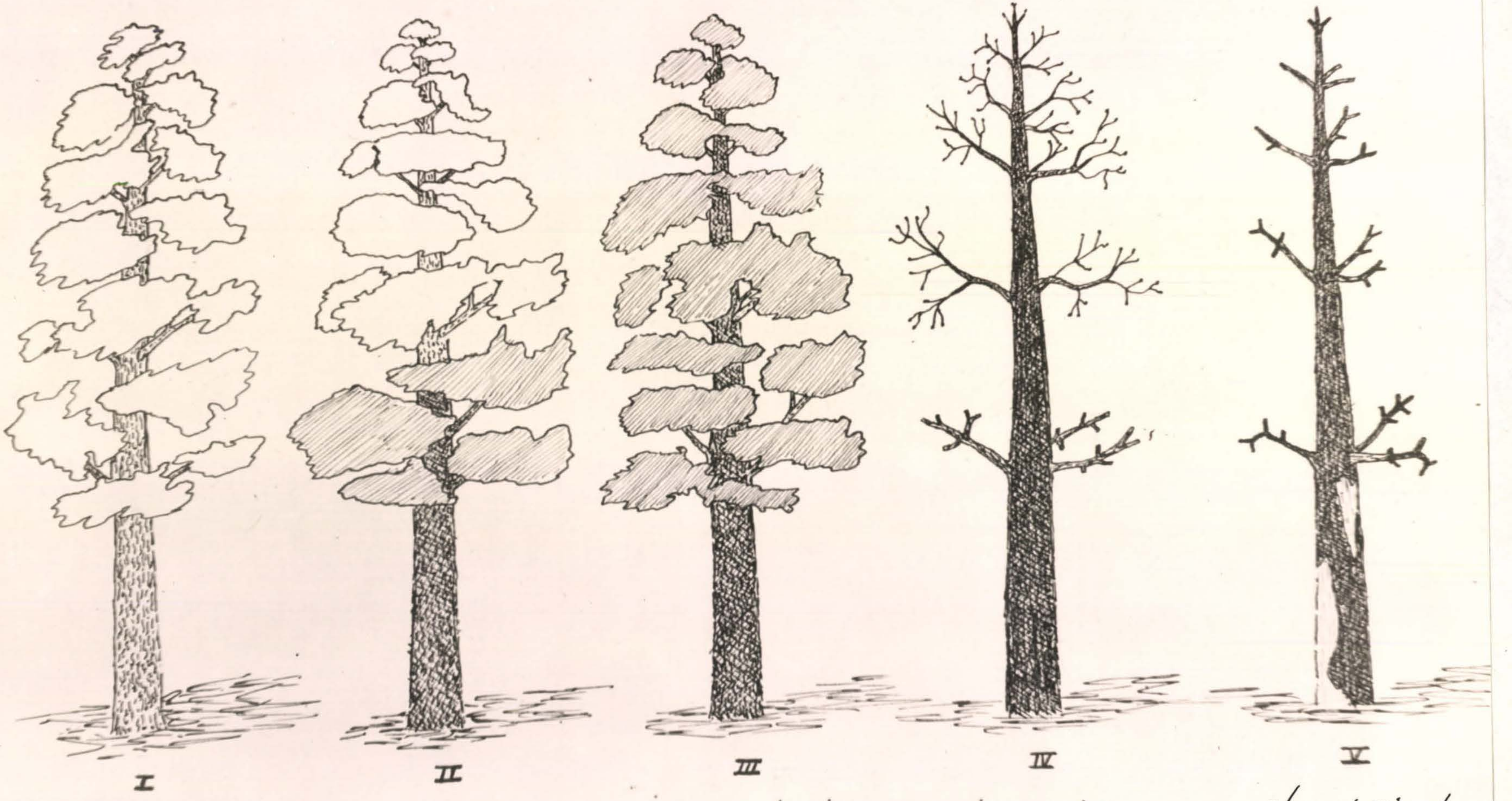


Fig 2- Illustrating degree of fire injury to trees on burned area. as classified in records of fire damage.

Mistletoe burn.

Class I - Uninjured by fire
Class II - Light fire injury
Class III - Medium fire injury
Class IV - Heavy fire injury
Class V - Killed by fire

the western pine beetle killed 20 yellow pine trees containing a volume of 12,500 board feet, within the area of the burn. No attacks occurred in November, 1917, following the fire. This is explained by the fact that at that time ~~the fire~~ the attacks of the overwintering broods had already occurred and no beetles were flying until the following spring.

During 1918, attacks occurred in many trees within the burn. Wherever fire injured yellow pine predominated heavy centers of attack formed. The volume board feet per acre killed within the burn exceeded that in the surrounding area by 200 to 34. During the year 220 trees were killed with a volume of 159,720 board feet, an increase over 1917 of 1100%.

In 1919 the loss was reduced to 50 trees, with a volume of 42,180 board feet. This represents a reduction of 77%. In 1920, 17 trees were killed with a volume of 15,680 board feet.

Table 1 : Progress of infestation on fire area and on surrounding area:

| Year: | Fire Area: | | Surrounding Area: | |
|---|---|---|---|---|
| | Number trees: | Volume: | Number trees: | Volume: |
| 1917 | 20 | 12,500 | 449 | 403,670 |
| 1918 | 220 | 159,720 | 508 | 516,130 |
| 1919 | 50 | 42,180 | 224 | 199,210 |
| 1920 | 17 | 15,680 | 181 | 160,980 |
| Total | 3 287 | 230,080 | 1,362 | 1,279,990 |

The course of the infestation within the burn was marked by a very pronounced increase during the season following the fire and a subsidence within the two following seasons to a point as low as that which existed before the fire.

Volume of Timber killed by Barkbeetles on Areas Surrounding Burn:

Outside of the burned area the volume of infested timber followed a course during the seasons of 1918, 1919 and 1920 quite different from that within the burn. A cruise was made of the entire surrounding area and an analysis of the beetle killed yellow pine by each mile zone from one to six miles from the center of the fire area. There was very little tendency toward an increase during 1918 and in the zones nearest to the fire there was a perceptible decrease. Following 1918 the infestation did not decrease as in the fire area but instead slightly increased.

Table 2 : Progress of infestation in each zone surrounding fire area:

| Zone: | Number of trees and volume killed each year: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1917 | | 1918 | | 1919 | | 1920 | |
| | Trees: | Volume: | Trees: | Volume: | Trees: | Volume: | Trees: | Volume: |
| 1 | 47 | 42,255 | 31 | 31,500 | 56 | 49,800 | 30 | 26,680 |
| 2 | 122 | 109,680 | 104 | 105,665 | 44 | 39,120 | 38 | 33,820 |
| 3 | 82 | 73,720 | 74 | 75,180 | 47 | 41,800 | 42 | 37,350 |
| 4 | 68 | 61,135 | 90 | 91,440 | 41 | 36,450 | 38 | 33,780 |
| 5 | 71 | 63,830 | 129 | 131,065 | 22 | 19,580 | 30 | 26,680 |
| 6 | 59 | 53,050 | 80 | 81,280 | 14 | 12,460 | 3 | 2,670 |
| Total | 449 | 403,670 | 508 | 516,130 | 224 | 199,210 | 181 | 160,980 |

Table 3 : Annual loss per acre on the fire area and on each of the surrounding zones for one year previous to fire and for three years after.

| Zone: | Acreage of yellow pine type in each zone. | Board foot loss per acre. | | | |
|---|---|---|---|---|---|
| | | 1917 | 1918 | 1919 | 1920 |
| Fire area | 800 | 16 | 200 | 53 | 20 |
| Zone 1 | 920 | 46 | 34 | 54 | 29 |
| Zone 2 | 3,440 | 32 | 31 | 11 | 10 |
| Zone 3 | 4,960 | 15 | 15 | 8 | 8 |
| Zone 4 | 4,000 | 15 | 23 | 9 | 8 |
| Zone 5 | 3,240 | 20 | 40 | 6 | 8 |
| Zone 6 | 1,200 | 44 | 68 | 10 | 2 |

A comparison of the course of the infestation both inside and outside of the burn is shown graphically by the Charts in Figs. 3 and 4.

## Classes of Fire Injured Trees Attacked:

Table 4 : Classes of fire injured trees attacked:

| Class of fire injury: | 1918<br>First year after:<br>Trees: | <br><br>Volume : | 1919<br>Second year after:<br>Trees: | <br><br>Volume : | 1920<br>Third year after:<br>Trees: | <br><br>Volume: |
|---|---|---|---|---|---|---|
| I - Uninjured by fire | 17 | 24,370 | 21 | 16,050 | 12 | 8,560 |
| II - Light fire injury | 81 | 60,140 | 11 | 8,260 | 3 | 2,620 |
| III - Medium injury | 84 | 49,910 | 18 | 17,170 | 2 | 4,500 |
| IV - Heavy injury | 38 | 25,300 | 0 | 0 | 0 | 0 |
| V - Fire killed | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 220 | 159,720 | 50 | 41,480 | 17 | 15,680 |

Table 5 : Number of trees attacked in each class of fire injury and percent of annual infestation in each class.

| Class of fire injury: | 1918<br>No. trees: | <br>% of infest: | 1919<br>No. trees: | <br>% of infest | 1920<br>No. trees: | <br>% of infest: | Total for period<br>No. trees: | <br>% of infest: |
|---|---|---|---|---|---|---|---|---|
| I | 17 | 8% | 21 | 42% | 12 | 71% | 50 | 17.5% |
| II | 81 | 37% | 11 | 22% | 3 | 17% | 95 | 33. % |
| III | 84 | 38% | 18 | 36% | 2 | 12% | 104 | 36. % |
| IV | 38 | 17% | 0 | 0 | 0 | 0 | 38 | 13.5% |
| V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total each year | 220 | 100% | 50 | 100% | 17 | 100% | 287 | 100.0% |

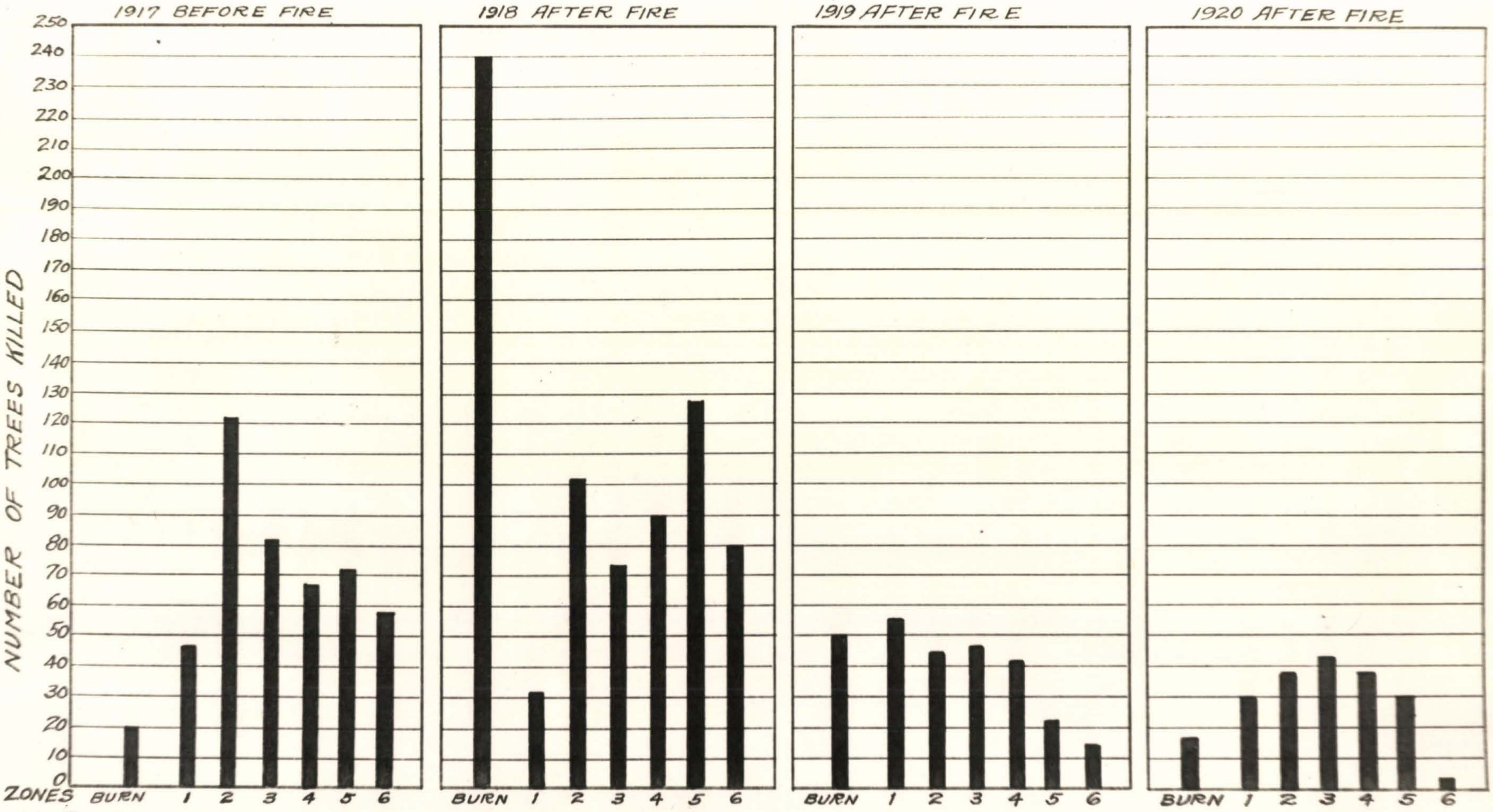


FIG 3- COMPARISON OF INFESTATIONS ON BURN AREA AND IN SURROUNDING ZONES FOR ONE YEAR BEFORE FIRE AND FOR THREE YEARS AFTER - MISTLETOE BURN

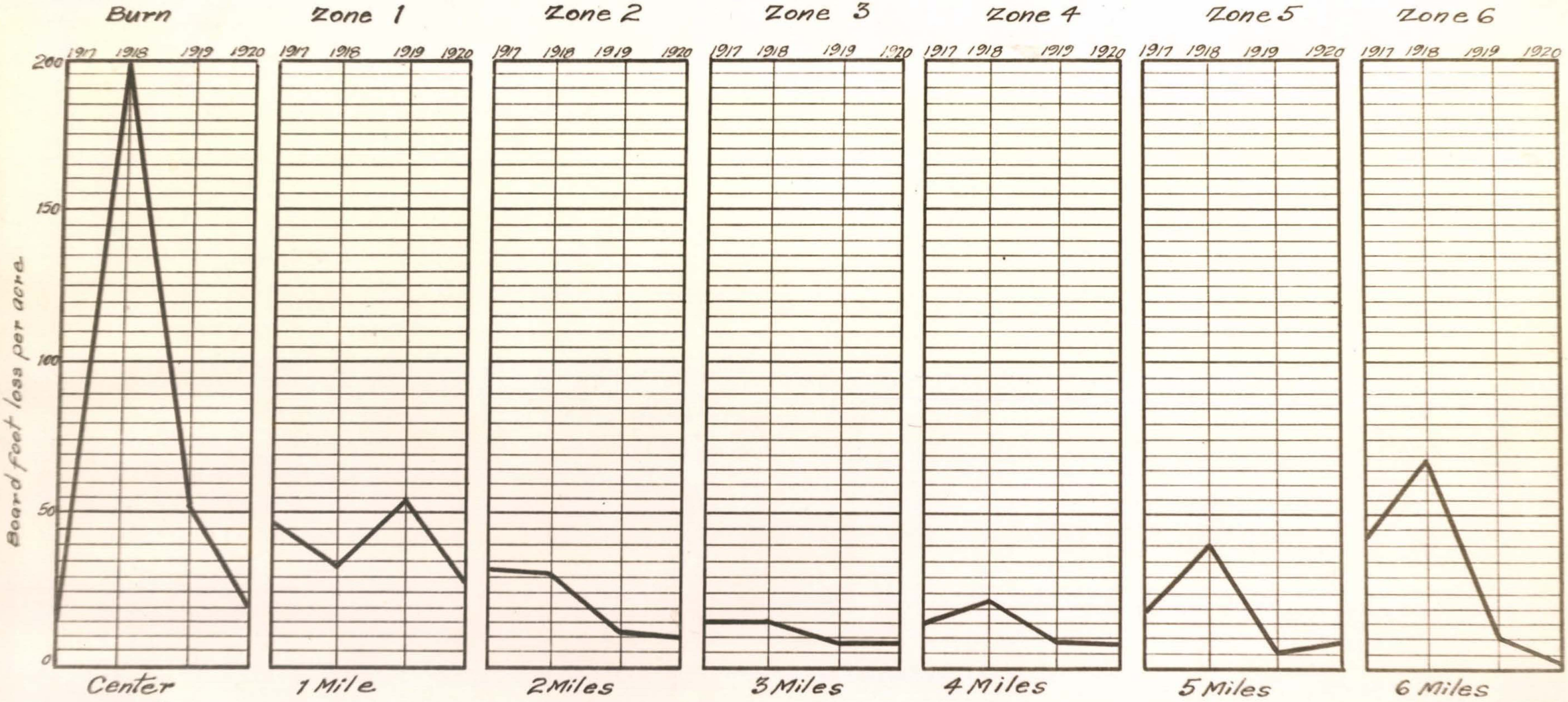


Fig 4 - Comparative rate of loss in board feet per acre killed by barkbeetles on burned area and on each of the surrounding zones during the season preceding fire and for three subsequent seasons. Mistletoe burn.

Table 6 : Number and precent of fire injured trees in each class attacked during first year after fire and also during the two succeeding years:

| Class of fire injury: | Total trees in each class: | Percent of total: | Number and percent of trees attacked annually | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1918 | | 1919 | | 1920 | | Class Total | |
| | | | No. trees: | % of class: | NO. trees: | % of class: | No. trees: | % of class: | Total trees: | % of total |
| I | 1,577 | 65.5% | 17 | 1. % | 21 | 1.3% | 12 | .76% | 50 | 3.1% |
| II | 573 | 24. % | 81 | 14. % | 11 | 2. % | 3 | .52% | 95 | 16.6% |
| III | 113 | 4.8% | 84 | 74.3% | 18 | 16. % | 2 | 1.7 % | 104 | 92. % |
| IV | 57 | 2.4% | 38 | 67. % | 0 | 0 | 0 | 0 | 38 | 67. % |
| V | 80 | 3.3% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 2,400 | 100. % | 220 | 9.2% | 50 | 2.1% | 17 | .7% | 287 | 12. % |

A selection of fire injured trees is shown in Fig. 5. There was a decided tendency on the part of the beetles to select trees in Class II which were only moderately injured. Some attacks occurred in trees uninjured in any way by the fire but it is evident that trees which sustained a light to medium fire injury were far more attractive to the beetles than any other trees on the burned area. Trees of this class were those which appeared to be likely to recover from the effects of the fire itself.

Period of Attraction to Trees within the Burn:

Trees in Classes I, II and III were attacked during the three seasons following the fire. This is shown graphically in Figure 6. In Classes II and III by far the greater part of these attacks, or more than 80 percent, occurred during the first season following the fire. During the second and third years after the fire the attacks in trees of these classes was still relatively more than the attacks in uninjured trees but to a much less extent than during the first season.

All attacks in Class IV occurred during the first season following the fire. The fact that no attacks occurred during the second and third seasons after the fire is readily explained as all trees in this class, not attacked by beetles during the first season, died as a result of fire injury before the period of

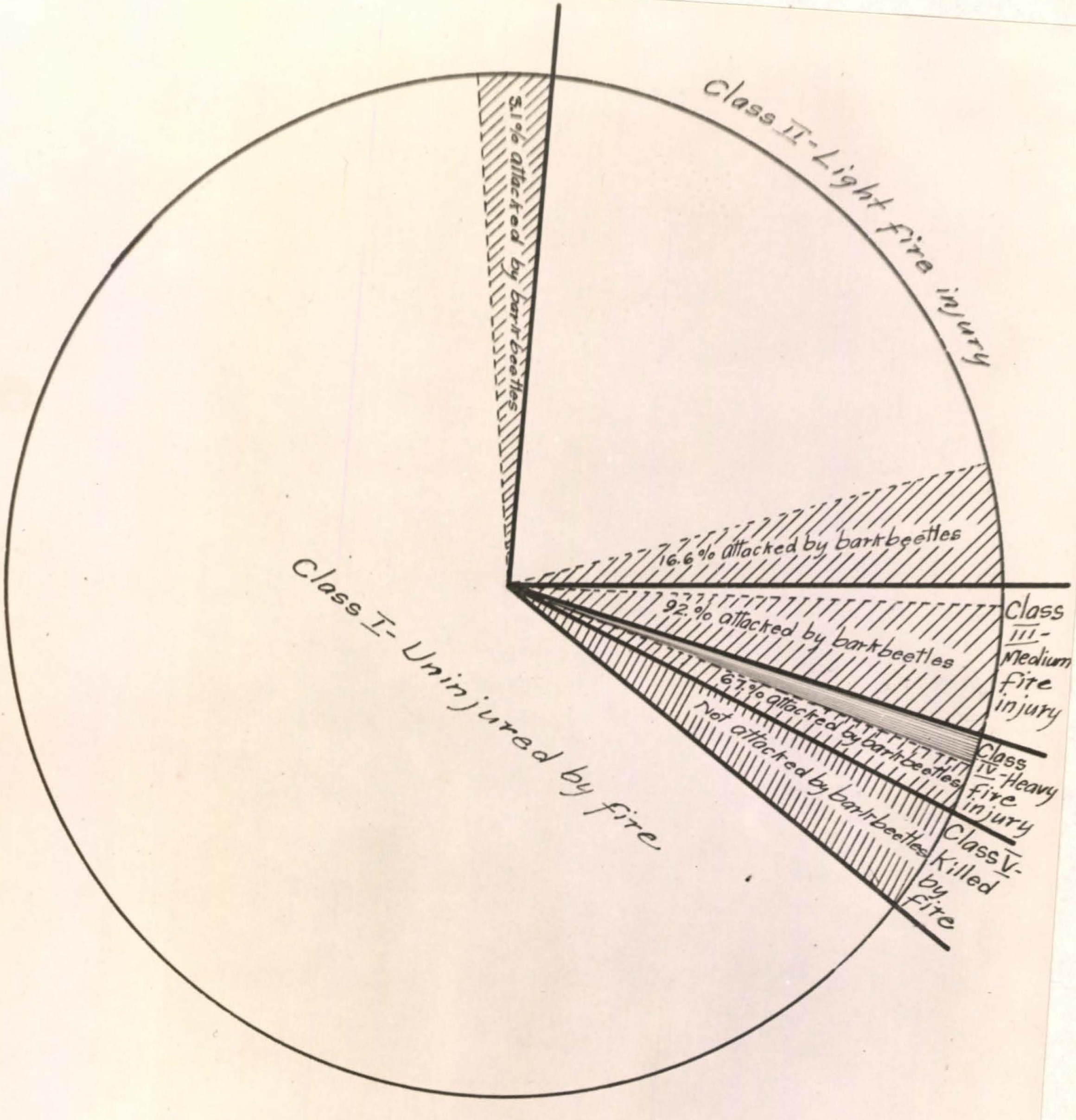


Fig 5 - Relative percent of fire injury and percent of trees in each Class attacked by tree killing insects. Mistletoe burn.

▨ Percent of trees attacked 1st, 2nd and 3rd years after fire

▤ Percent of trees dying 2nd year from fire injury

▥ Fire killed trees not attacked by barkbeetles

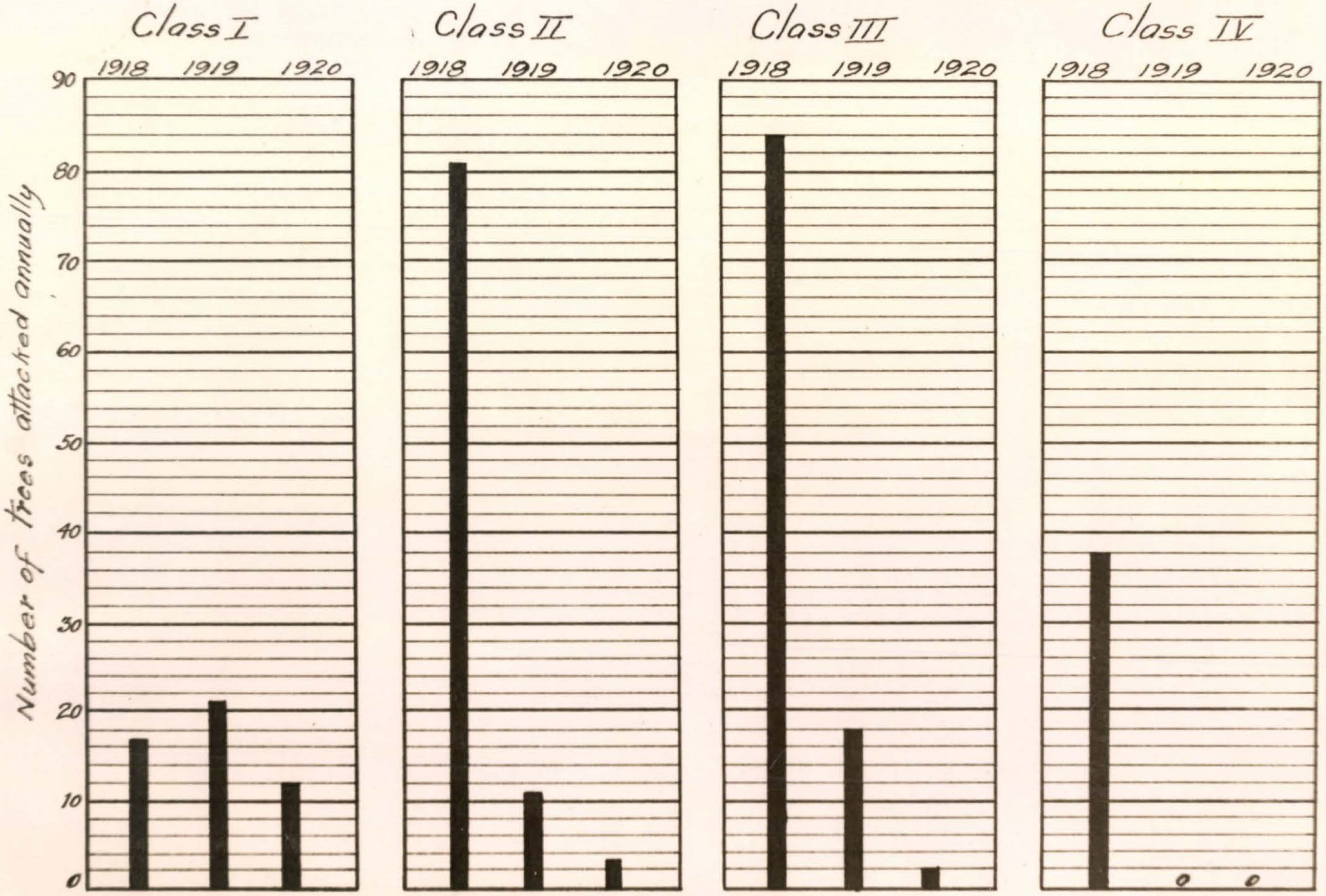


Fig 6 - Relative number of trees attacked annually by barkbeetles in each class of fire injury for three seasons subsequent to fire. Mistletoe burn.

attack of the second season.

While the period of attraction to fire injured trees was extended during the second and third season it is evident that the concentration of beetles within the burn resulted from the attraction during the first subsequent season.

Development of Broods in Fire Injured Trees:

1. Effect of Fire on Broods in Outer Bark of Infested Trees:

There were six yellow pine trees infested with broods of the western pine beetle standing within the burn at the time that the fire occurred. The broods in these trees consisted mainly of full grown larvae and a few pupae in the outer bark. All of these trees were exposed to heat from a ground fire of moderate intensity, and the outer bark near the base received more or less scorching. In five of these trees the broods continued to develop following the fire and a normal emergence occurred from them the following spring. In one tree however the broods in larval and pupal stages were killed on one side of the trunk near the base where the heat had been severe.

2. Mortality of Broods in Trees Attacked After Fire:

During the season of 1916 it was found that many of the western pine beetle broods infesting fire scorched trees were dying in the young larval stages. This high mortality was apparently due to "sour sap" an extremely moist condition of the inner bark which was found to be prevalent in a majority of the fire injured trees in this area. This excess moisture condition seriously interferes with development of young broods of the western pine beetle and frequently kills them before they reach the outer bark.

In order to obtain some idea of the extent of this mortality a study was made of the number of beetles attacking the bark surface of sour sap trees as compared with the subsequent progeny which emerged. A total of 272 square feet of bark was collected from 28 trees which had been attacked and abandoned by the beetles, or an average of nearly 10 square feet to the tree. An effort was made to select fairly representative trees and the bark sections were collected at varying heights from each tree ranging from 6 to 70 feet from the base.

The number of entrance holes where one pair of beetles entered the cambium were counted and also the number of exit holes from the same bark sections. Previous studies had determined that the number of beetles entering through each entrance hole averages 2.59. Upon this basis it is possible to arrive at the following comparison of the number of beetles which entered and emerged from fire injured trees.

| Fire injured trees: | |
|---|---|
| No. square feet of bark analysed ................ | 272 |
| Total number entrance holes .................... | 1372 |
| " " beetles attacking (1372 x 2.59) ..... | 3553 |
| " " progeny emerging (exit holes) ..... | 3277 |
| Reduction in emergence over attack ............... | 276 |

This analysis indicates that although the fire injured trees attracted beetles to such an extent as to cause a concentration within the burn, at the same time they afforded a very unfavorable breeding ground for the insects and in the end contributed toward an actual reduction of their numbers.

## Development of Broods in Trees Attacked Outside of Burn:

In order to compare the mortality of the beetles in fire injured trees with that in normal infested trees a similar study was made of bark from trees outside of the burn. A total of 341 square feet of bark was collected from 76 trees. The results of these counts were as follows:

Normal trees:

| | |
|---|---|
| Square feet of bark analyzed .................... | 341 |
| Total number entrance holes .................... | 2048 |
| " " beetles attacking (2048 x 2.59) .. | 5294 |
| " " progeny emerging (exit holes) .... | 22807 |
| Excess of emergence over attack ................ | 17513 |

A direct comparison of the average attacks and emergence per square foot unit on fire injured and normal trees stands as follows:

| Condition of trees: | Attack: | Number of beetles attacking: | Number of beetles emerging: | Increase or decrease over no. attacking: |
|---|---|---|---|---|
| Fire injured | 5 | 13 | 12 | 1 decrease |
| Normal | 6 | 15.5 | 67 | 51 increase |

A graphic comparison is also shown in Fig. 7. In normal trees there was an increase during 1918 of approximately 330% whereas in the fire injured trees there was an actual decrease of about 8%. To this extent the fire acted as a controlling factor by reducing the numbers of beetles that were attracted into the burned area.

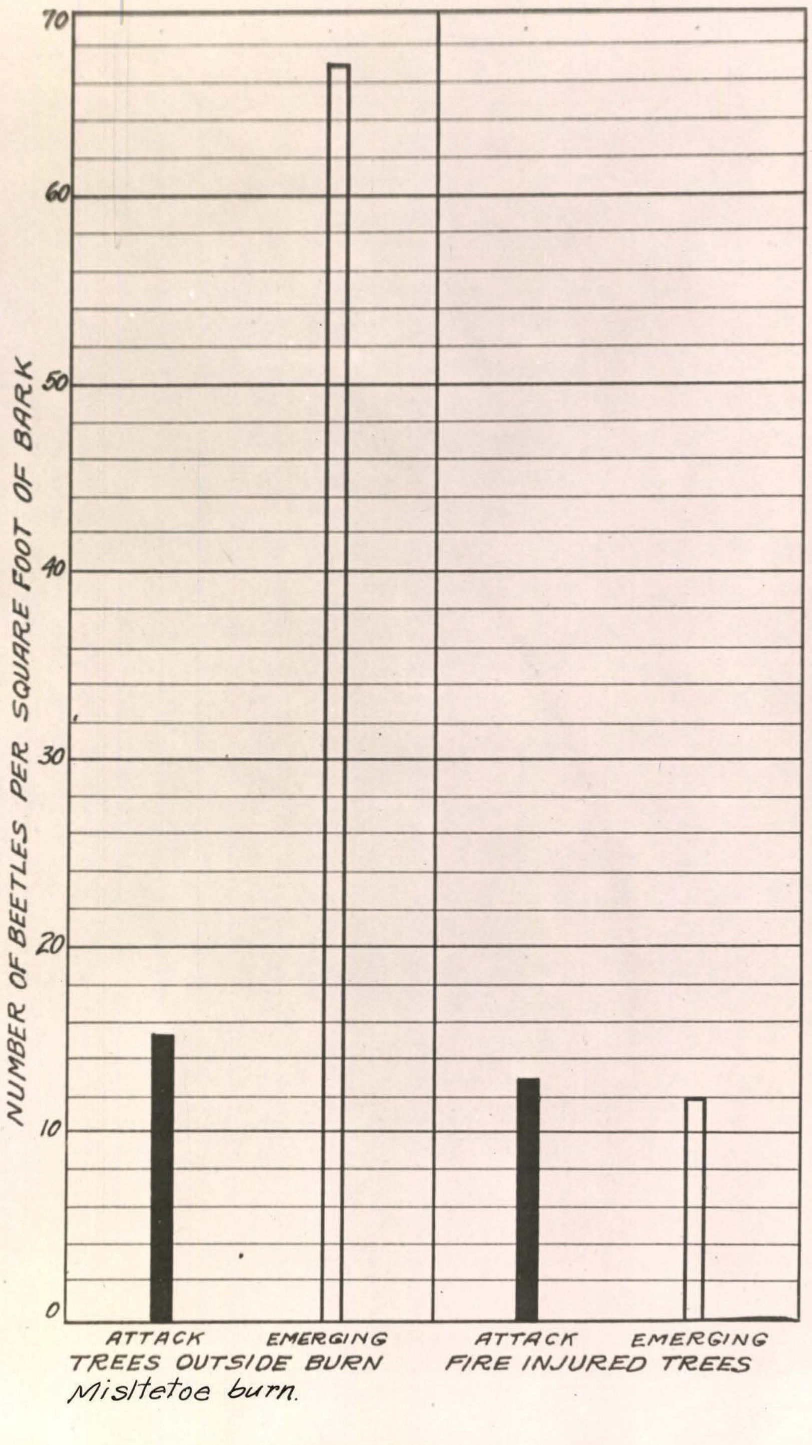
## Summary of Results on Mistletoe Burn:

The outstanding results of this study are the following:

1. That the fire resulted in an immediate loss of approximately .7% of the merchantable pine volume. Of the remainder 3.7% was injured to an extent that its recovery was improbable. Still 30.6% was scorched to a varying extent but as the cambium was uninjured such trees had a very good chance of recovery. The remaining 65% of the stand was uninjured by fire.

2. This fire, which occurred late in October, produced no disturbance

FIG 7 - COMPARISON OF BROOD DEVELOPMENT IN FIRE INJURED TREES AND IN TREES UNDER NORMAL CONDITIONS ADJACENT TO BURN



Mislteoe burn.

of the infestation in and around the area during the remainder of that season.

3. Throughout the season following the burn, fire injured trees formed an attraction which caused a concentration of beetles in the burned over area. As a result the volume of infested timber within the burn increased 1100 percent over that on the same area during the preceding year.

4. The attraction of the beetles to individual trees was largely determined by the character of the fire injury. A decided preference was shown for trees in which the lower trunk and foliage had been moderately or lightly scorched. This attraction was most pronounced during the first season following the fire. During the second season following the fire the beetles showed but little more preference for the fire injured than for uninjured trees.

5. This concentration of beetles within the burn did not breed up an epidemic infestation that continued to increase within the burn or to spread to surrounding areas. During the second year after the fire the infestation both in the burn and in the surrounding area returned to a point very close to that which existed before the fire.

6. The volume of infestation in the surrounding area was apparently influenced by developments within the burn. During the year following the fire the volume of infestation in the zones immediately adjoining and within three miles of the burn was reduced, apparently due to the attraction of beetles to the fire injured trees in the burned over area. The infestation in zones more than three miles distant from the burn increased slightly during the same season.

7. A study of bark collected from beetle attacked fire injured trees showed that due to excessive moisture in the inner bark a heavy mortality occurred in the western pine beetle broods. A comparison indicates that the numbers of beetles emerging from fire injured trees was 8% less than the numbers of parent adults which attacked, resulting in a slight reduction of the second generation of the beetle population in the burned area.

## THE SISKIYOU BURN:

This area was also studied with the same detail as the Mistletoe burn just described. The fire occurred on August 15, 1918, and covered about 200 acres situated approximately 4 miles south of the Mistletoe unit.

Type and slope conditions were quite similar to those on the Mistletoe burn but the fire was of somewhat greater severity as shown by the correspondingly greater damage to mature trees. Cruises were made in which the fire injured trees were classified on the same basis as in the Mistletoe burn.

Table 7 : Yellow Pine Trees Classified According to fire damage.

| Class: | Description : | Number trees: | Percent: |
|---|---|---|---|
| I | Uninjured by fire | 176 | 31% |
| II | Light fire injury | 205 | 37% |
| III | Medium fire injury | 52 | 9% |
| IV | Heavy fire injury | 114 | 20% |
| V | Killed by fire | 18 | 3% |
| Total | | 565 | 100 % |

At the time of the fire there were two yellow pine trees with a volume of 260 feet which had been infested by the western pine beetle during the early summer preceding the fire. These trees represented the first seasonal generation and were nearly abandoned at the time. The attraction of fire injured trees in concentrating beetle attacks within the burned area was effective within a few days after the fire occurred. In this respect the effects of the Siskiyou fire differ from those of the Mistletoe area where the beetles did not concentrate until the season following the fire. This difference is easily explained by the fact that the Siskiyou fire occurred during the seasonal flight period of the beetles while the Mistletoe fire occurred in the fall after this activity had subsided.

During the latter part of August and through September the beetles attacked 41 new trees with a volume of 44,130 board feet, an increase of 1,950% over the number killed by the preceding generation.

During 1919 the insects continued to concentrate in the fire area and the loss continued, increasing 51% over that of 1918. In 1920, however, the third year after the fire, there was a pronounced decline in attack and the loss for that season averaged 93.5 less than that of 1919.

Table' 6 : Western Pine Beetle Infestation in Siskiyou burn:

| Season of attack: | | No. trees: | Volume: | Percent in No. trees increase or decrease over preceding year. | |
|---|---|---|---|---|---|
| | | | | Increase: | Decrease: |
| 1918 | 1st generation before fire | 2 | 260 | | |
| 1918 | 2nd generation after fire | 41 | 44,130 | 1950% | |
| 1919 | annual loss | 62 | 74,990 | 51% | |
| 1920 | annual loss | 4 | 3,150 | | 93.5% |

The preceding tables show that the infestation on this burn increased following the fire, in about the same degree as that on the Mistletoe burn, and that the cycle of increase and decrease was of practically the same duration. The heavy increase immediately after the fire was followed by an equally pronounced decrease within two seasons.

This infestation within the burn was distributed in the following classes of trees:

| Class: | 1918 | | | 1919 | | | 1920 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Trees: | Volume: | %Volume: | Trees: | Volume: | %Volume: | Trees: | Volume: | %Volume: |
| I | 2 | 1,110 | 2.3% | 2 | 2,370 | 3% | 0 | 0 | |
| II | 8 | 8,680 | 20. % | 15 | 13,050 | 17% | 0 | 0 | |
| III | 6 | 11,260 | 25.5% | 6 | 2,250 | 3% | 4 | 3,150 | 100% |
| IV | 19 | 4,790 | 10.8% | 39 | 57,320 | 77% | 0 | 0 | |
| V | 6 | 18,290 | 41.4% | 0 | 0 | 0 | 0 | 0 | |
| Total | 41 | 44,130 | 100 % | 62 | 74,990 | 100% | 4 | 3,150 | 100% |

### Course of Infestation in Surrounding Areas:

The Siskiyou fire was so located that a study of the infestation by surrounding zones was not practical. However., the general course of the infestation in the surrounding region can be determined by the figures showing the same progress in the area surrounding the Mistletoe burn.

No study was made of brood mortality in trees either within or outside of this fire area, but as the effects of the fire differ but little from those on the Mistletoe burn, there is reason to believe that the same high mortality in fire injured trees resulted.

### The Chinquapin Burn:

Another area which was studied in less detail than either of the others is the Chinquapin burn which is located 26 miles southeast of Ashland, Oregon. This fire occurred in September 1915 and covered 220 acres. The character of this fire was practically the same as that on the Mistletoe and Siskiyou burns.

The attractive influence of the fire injured trees on this burn/was most marked during the season of 1916, the year following its occurrence. During this season there was a concentration of the western pine beetle within the area resulting in an increase of 475% over that on the area in 1915. The greater part of the attacks were in trees which had been scorched by the fire. While the infestation within the burn increased 475% during this season throughout the surrounding area there was a decrease of 68%.

In 1917 the infestation decreased both within the burn and in the surrounding area. This was followed in 1918 by an increase both within the burn and the surrounding area.

On the whole the data from this area indicates that the main effect of this fire, the concentration of beetles within the fire area, had disappeared by the close of the second season after the fire.

## EFFECTS OF CONTROLLED BURNING UPON BARKBEETLE INFESTATIONS:

A fire of an entirely different character was studied in Siskiyou County, California, where a large lumber company during the season of 1920 practised on its own holdings what has been termed controlled or "light" burning. The method consisted of burning the area at night in small blocks of not more than 160 acres surrounded by fire lines. During the period from June 15, 1920 to about October 30, 1920, approximately 12,000 acres were burned over by this system. The object of this operation was to lessen the fire hazards within a tract where the company contemplated logging in the near future.

The character of the area differed essentially from those previously described in that there were few steep slopes, a very large part of the acreage being relatively flat. Because of this and the fact that the fires were controlled and the burning was carried on at night there was very little evidence of severe damage to merchantable trees such as occurred on the burns just described. The character of this fire also differed from the others in that the burning operations were extended over a considerable period of time.

Before the controlled burning operations were started in 1920, representatives of the Bureau of Entomology made a 100% cruise of one section of 640 acres marking all insect infested trees. This section, which was among the first to be covered by the burning operations, was burned over in July. One month later a second cruise was made of the same section. These examinations resulted in the following data:

| | No.trees | Vol. |
|---|---|---|
| Trees infested at time of fire (1st generation,1920) | 43 | |
| Brood mortality observed in infested trees exposed to fire | 0 | |
| No. standing trees attacked subsequent to fire | 78 | |
| No. trees burned down by fire in butt scars and subsequently attacked by beetles | 12 | |
| Total loss on section during 1920 (year of fire) | 133 | |
| " " " " " 1919 (year preceeding fire) | 79 | |
| Increase during 1920 | 54 | |

It would appear from these figures that this fire caused some attraction which brought beetles into the area during the latter part of the summer in which the fire occurred. However no such concentration as that found on the other burns studied was observed. The failure of the beetle to concentrate on the light burned area may have been due both to the absence of trees sufficiently injured by the fire to attract the beetles and also to the fact that for the remainder of the flight period of that season fires were running through nearby timber creating conditions similar to those on the section that was cruised.

This section was logged off the following spring, so that no follow up studies were possible.

At the time that the burning operations were in progress the same company under the technical advice of the Bureau of Entomology organized a project for the control of the western pine beetle on a tract of 44,000 acres adjoining the 12,000 acres ~~burning~~ covered by controlled burning. From cruises made during the course of this project it was found that the loss during 1920 on the entire tract averaged 77 trees per section of 112 board feet per acre or 1.4% of the total pine stand. Direct control measures against the beetles were started in the fall of 1920. The methods consisted of locating the infested trees, felling, and peeling and burning the infested bark. Two sections that had been burned over by the controlled burning of the summer extended into the area that was included in the insect control work. As a 100% cruise was made of these two sections and the adjoining area it was possible to compare the overwintering infestation on the burned and non burned areas.

| | |
|---|---|
| Number trees per section on burned area ........ | 189 |
| Number of trees per section on adjoining unburned area ............. | 170 |

It is evident that in this class of fire a very limited concentration of beetles resulted. Practically all of the area covered by the light burning operations in 1920 was logged off during the following two seasons so that it was possible to study only the results which developed immediately after the fire. As both control work and logging operations were carried on within the area subsequent to the fire the natural tendencies of the infestation were considerably disturbed.

## GENERAL SUMMARY

Forest fires of sufficient severity to scorch the bark, cambium, and foliage of yellow pine trees produce types of injury which make certain trees especially attractive to the western pine beetle. Many trees which have been only moderately injured by the fire and apparently capable of recovering from this injury are attacked and killed by the beetles following a fire of this character.

The attraction of fire injured trees often causes a concentration of beetles within a burned area which lasts for one or two seasons following the fire. This attraction will bring beetles in from surrounding forest areas for a distance of two or three miles.

The concentration of barkbeetle attacks in fire injured trees within a burned area does not breed up an epidemic condition. The loss from barkbeetle attacks in non injured trees either within the area of the burn or in the surrounding forest is not materially increased as a result of this concentration.

Fires which are not severe enough to burn the bark from infested trees are of little value in controlling barkbeetle infestations. Fires of moderate severity will not kill barkbeetle broods in infested trees that are on the area at the time of the fire.

While fire injured trees attract barkbeetles in considerable numbers they do not always afford favorable breeding conditions for the new broods. Where moist inner bark or "sour Sap" develops, a high mortality results before the broods mature. Conditions have been observed where this mortality is high enough to act as a controlling influence, fewer beetles actually emerging from these trees than attacked them.

Where fires are of very light severity or where the area burned over is of great extent, concentration of beetles is much less evident than on small areas where the fire has been moderately severe. By and large, the effect of forest fires upon barkbeetle infestations, as brought out by these studies, show that the fires can have no possible benefit in reducing beetle losses through killing the beetles, unless the fires are severe enough to destroy the trees; neither do they have any permanent effect in increasing beetle losses in surrounding timber.

The principal role of the barkbeetles in connection with forest fires is in the added destruction by the beetles of moderately fire injured trees, which otherwise would have survived the fire.

Thus barkbeetles are an agency which supplement and increase the timber losses initiated by forest fires, while on the other hand fires have but little influence in permanently increasing the losses caused by barkbeetles.

## Plate 1. Explanation.

Photographs of fire injured trees which attract barkbeetle attacks.

Figure 1. Class III. Two examples of fire injury showing base and middle portions of trunks fire charred and almost all of foliage scorched. The buds of the new needle growth were injured toward the top of the tree. The larger trees suffering this degree of fire injury have some chance to recover if not attacked by insects. They are, however, more attractive to barkbeetles than trees in any other class of fire injury. Over 80% of the trees in this class were attacked the first season after the fire.

Figure 2. Class IV. A group of three small trees showing heavy fire damage. The trunks of these trees were scorched for their entire length and the greater part of the foliage was burned away. The terminal buds were killed, although the cambium remained green until the following season. This class is of medium attraction to barkbeetles, during the first season after the fire only. Trees of this class died as a result of the fire injury and none of them were attacked by barkbeetles after the first year subsequent to the fire.

PLATE 1.

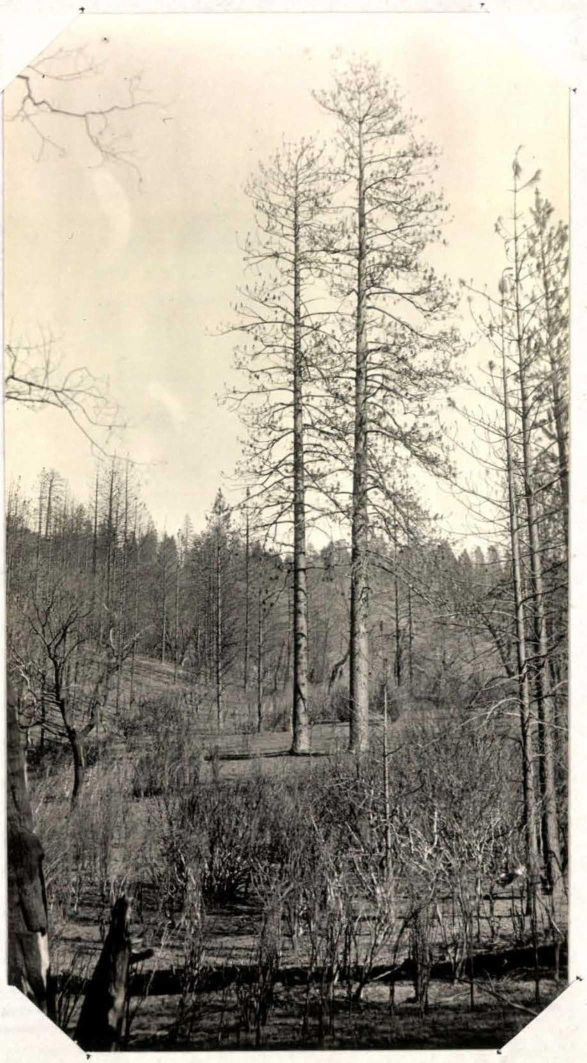


Fig 1.

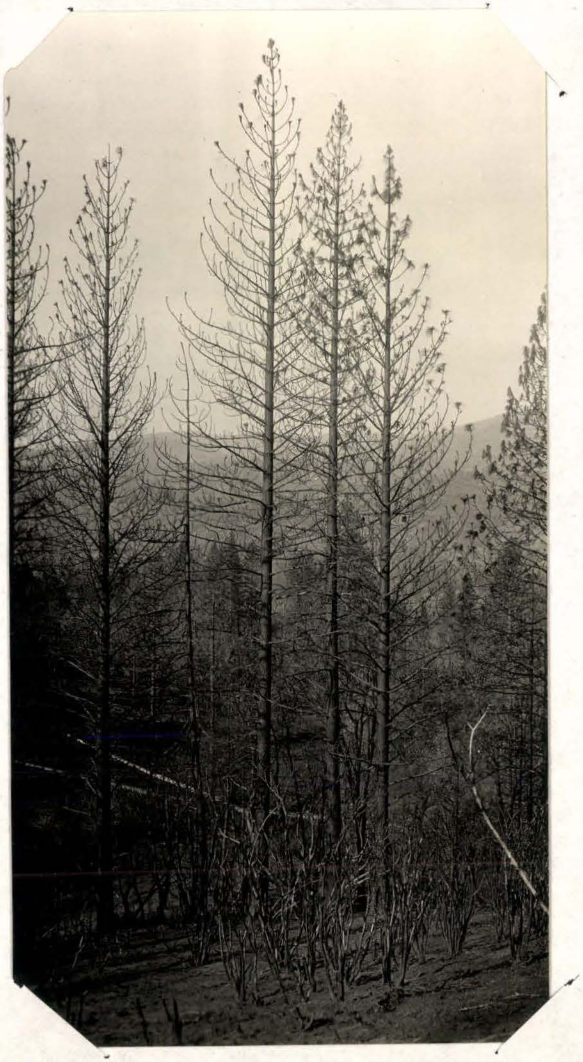


Fig 2.